COMMERCIAL LOBSTER CULTURE FEASIBILITY STUDY CLARK'S HARBOUR NOVA SCOTIA

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Fisheries and Marine Service

Industry Report 102

August 1978

1977 COMMERCIAL LOBSTER CULTURE FEASIBILITY STUDY CLARK'S HARBOUR, NOVA SCOTIA

by

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Foreword

Interest in the commercial feasibility of lobster culture, using the eyestock ablation technique, has been shown by a number of lobster pound operators in all of the Maritime provinces. The 'Island Lobsters' facility at Clark's Harbour, Nova Scotia, was selected as a demonstration site, since this facility was designed to hold the test lobsters in individual containers, thus eliminating cannibalism (a perennial problem in live holding of molting lobsters) and minimizing the cross contamination of the lobsters due to water-borne bacteria.

Funds in support of this feasibility trial were provided under the Fisheries Development Industrial Development program, Fisheries and Marine Service. Contractual arrangements were administered by the Department of Supply and Services, and the scientific direction was provided by the Disease and Nutrition Section, Fisheries and Environmental Sciences of the Resource Branch, Fisheries Management.

ABSTRACT

Bishop, F. J. and J. D. Castell. 1978. Commercial Lobster Culture Feasibility Study. Fish. Mar. Serv. Ind. Rep. 102:

A federally assisted project was undertaken to determine the feasibility of growing captive American lobsters (Homarus americanus) through one molt under commercial conditions. To enhance the lobster growth rate and ensure adequate survival, this required a combined application of bilateral eyestalk ablation, good diets and disease prevention methods.

A total of 3,435 male lobsters, each weighing between 400 and 600 g. were used in the study. Each lobster was held in an individual container supplied with ambient seawater in a commercial lobster pound at Clark's Harbour, Nova Scotia. A group of 300 lobsters were kept as intact controls and bilateral eyestalk ablations were performed on the rest. The molting incidences during the 4 months project were 63.5% for the ablated lobsters and 12.3% for the controls. The mean post-molt weight gain of 78 ablated lobsters was 71.5% ($\pm$ SD 9.2). Some post-molt mortalities were attributed to physical restriction during molting because of undersized holding containers. The largest portion of the mortalities, however, resulted from water supply interruptions. A prolonged interruption of the water supply in the fourth month caused high mortalities of ablated lobsters at post-molt stages of up to 3 months; consequently, shipping and marketing tests on the lobsters of increased size could not be performed. The information collected in the course of the project, however, indicates that a feed-lot operation of this nature is technically feasible and could also be an economically viable enterprise once relatively straight forward problems are solved.

RÉSUMÉ

Bishop, F. J. and J. D. Castell. 1978. Commercial Lobster Culture Feasibility Study. Fish. Mar. Serv. Ind. Rep. 102

Un projet assisté par le gouvernement fédéral est entrepris afin d'etudier la possibilité d'élever les homards américains (Homarus americanus) en captivité sous des conditious commerçiales au cours d'une mue. Afin d'accélérer le rythme de croissance et d'assurer une survie adéquate des homards, il faut une application combinée de l'ablation bilatérale du pédoncule oculaire, de bons régimes et des méthodes de prévention de la maladie.

Nous utilisons dans cette étude 3,435 homards mâles, pesant chacun entre 400 et 600 g. Chaque homard se trouve dans un compartiment individuel approvisionné d'eau de mer sous conditions marines ambiates, dans un vivier commerçial à Clark's Harbour, Nouvelle Ecosse. Trois cent homards servent de témoin tandis que les ablations bilatérales du pédoncule sont exécutées sur le reste. Les fréquences des mues pendant le projet de 4 mois sont 63.5% chez les homards opérés et 12.3% chez les témoins. La moyenne des gains pondéraux après les mues de 78 homards opérés est 71.5% ($\pm$DS 9.2). Quelques mortalités après la mue sont attribués à une restriction physique pendant la mue causée par des compartiments trop petits. Cependant, la plus grande partie des mortalités est le résultat des interruptions de la circulation d'eau. Une interruption prolongée de la circulation d'eau au cours du quatrième mois produit un grand nombre de mortalités chez les homards opérés qui avaient mue jusqu'à 3 mois auparavant; ainsi il ne nous a pas été possible d'effectuer des tests d'expédition et de vente des homards de taille augmentée. Cependant, les informations recueillés au cours du projet indiquent qu'une application commerçiale de ce genre est technicalement possible et peut être une enterprise économiquement viable dès que des solutions aux problèmes relativement simples seront trouvées.

INTRODUCTION

Recent studies conducted by the Department of Fisheries and Environment, Resource Branch in Halifax, N. S. and St. Andrew's, N. B. have demonstrated that bilateral eyestalk ablation and the feeding of an adequate and balanced diet are together capable of increasing the growth of captive lobsters without the high mortalities previously associated with ablated crustacea (Castell et al, 1977; Mauviot and Castell, 1976). Smith (1940) suggested that the high molt mortality previously associated with ablated crustacea had been largely a product of improper feeding. Mauviot and Castell (1976) later confirmed this in their study on ablated juvenile and adult American lobsters (H. americanus) when it was found that in terms of their growth and survival characteristics, ablated lobsters were more sensitive to dietary composition than unablated controls. In a pilot scale study, ablated lobsters grew at an accelerated rate and gained significantly more weight after molting than their non-ablated counterparts. No significant differences in taste and texture characteristics were found when comparisons were made between ablated, intact control and wild lobsters.

The question arising from this work was whether eyestalk ablation could be applied in an industrial context to increase the value of landed lobsters by growing them further in captivity. The economic feasibility of a commercial application of these techniques is enhanced by the fact that comparatively low cost 'canner' size lobsters (1/2 - 3/4 lb.) reaching 'market' size (3/4 - 1 1/2 lbs.) after one molt could be sold at a higher market price per pound. Alternatively, 'market' size lobsters grown through one molt that enter the 'select' size bracket (1-1/2 - 2 lbs.) could also be sold at corresponding higher prices. One may also be able to take advantage of the two annual peaks in the market values of 'market' and 'select' lobsters (see Figure 1) by planning the growth period so that its products are ready at one of those peaks.

In July 1976 the Federal and Provincial Fisheries Departments and Island Lobsters Ltd. undertook a joint project whose principal objective was to determine the feasibility of applying the ablation and feeding techniques under commercial conditions. Island Lobsters Ltd. owned and operated the facilities in Clark's Harbour, N. S. known as the 'Swim Pound'. The project involved the use of over 10,000 lbs. of lobsters that were cared for by locally available manpower. Unfortunately, severe disease problems were encountered.

The disease known as gaffkemia is caused by the highly virulent bacterium Aerococcus viridans variety homari, which may only be transmitted from one lobster to another through a rupture of the integument (Stewart et al, 1969). Eyestalk ablation produces such a rupture. This fact, in conjunction with partial effluent recirculation and high initial gaffkemia incidences in the project's Northumberland Strait 'canner' lobsters, caused a spread of this fatal disease throughout the facilities. Subsequent disinfection and separation of the water intake and discharge lines were not sufficient to prevent the spread of gaffkemia again when new groups of infected lobsters were acquired. In spite of their being held in individual containers, the new 'canners' were able to inflict injuries on one another by reaching over or under container partitions, thus contributing to a further spread of the disease. The project was prematurely terminated when its water supply was disrupted by a storm, requiring the surviving lobsters to be transferred to community tanks.

A set of practical guidelines was drawn up based on the experience acquired in the course of the project. The following is a brief outline of its main points.

1. Under no circumstances should there be any water recirculation (unless gaffkemia is absent) and complete physical isolation of the individual lobsters is required.

2. The use of freshly caught lobsters would provide a greater measure of control over their quality and disease incidence since by dealing directly with the lobster fishermen, holding facilities that have been contaminated with gaffkemia are avoided altogether.

3. The lobsters' claws should be immobilized with rubber bands and no 'plugged', injured or weak lobsters should be accepted.

It was with these points in mind that a second commercial lobster culture feasibility study was started in May, 1977 conducted jointly by Island Lobsters Ltd., Clark's Harbour, N. S. and Department of Fisheries and Environment.

PROJECT OBJECTIVES

The 1977 lobster culture project constituted a second attempt to determine the feasibility of growing lobsters commercially through the application of eyestalk ablation, good nutrition and disease control concepts. The main questions relating to commercial viability that were to be answered in the course of this project are outlined as follows:

Survival

Accurate records of lobster mortalities were to be kept since this factor alone could severely limit commercial viability. The mortalities associated with initial handling, ablation, molting and shipment to retailers was to be documented.

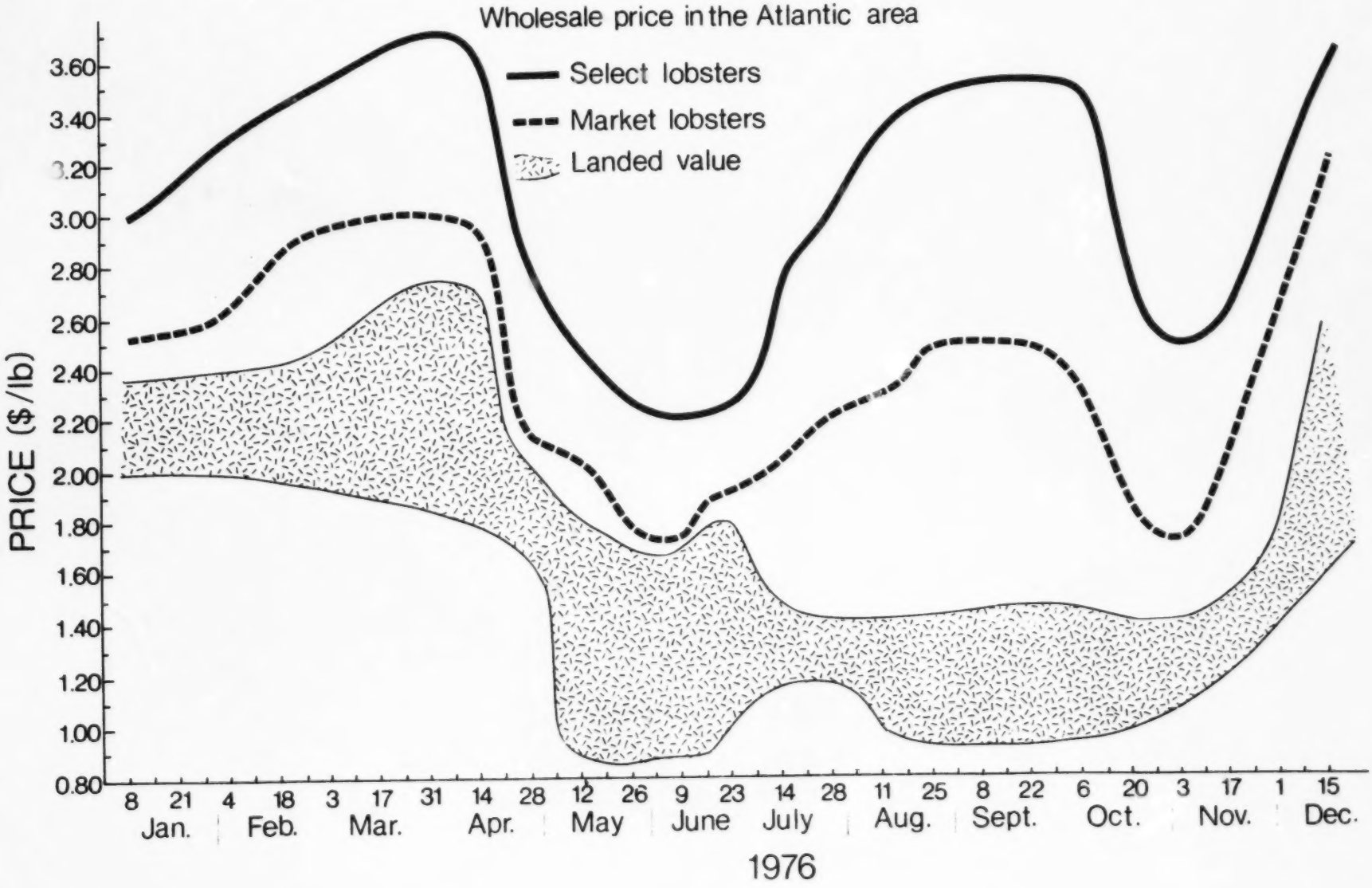
Weight Gain

Although ablated lobsters had gained significantly more weight after molting than their normal counterparts in the pilot study, the question here was whether the same could be said for lobsters held under commercial conditions. In order to answer this question individual normal and ablated lobsters whose initial weights were known would have to be monitored throughout the project.

Feed Development

Feed for the first commercial lobster culture project needed further development to improve its

Figure 1: Seasonal variation in the landed values and market prices of Maritimes area lobsters caught in 1976; courtesy of Fisheries Statistics, D.F.E. and Mr. M. Swim, Island Lobsters Ltd. The shaded area represents the range of prices paid to fishermen at various locations for both 'market' and 'canner' size lobsters.



consistency. It was hoped that this would be achieved by using more suitable ingredients and binders, and by improving on the feed preparation methods.

Feed Conversion

As is the case in other forms of aguaculture or mariculture, the feed costs involved in a lobster culture venture could drastically impair its profitability. The total feed consumptions of the normal and ablated groups were to be recorded separately so that any differences between their feed conversion values could be documented and compared.

Post-Molt Interval

It was anticipated that the water temperatures at the Clark's Harbour site would be lower than the heated water temperature of the pilot study (15°C). Therefore, a longer post-molt interval could be expected before the lobsters would be adequately hardened and meated. This interval would have to be found by determining the percentage edible meat of lobsters at various post-molt times. The serum protein levels of these lobsters were also to be measured to determine whether the direct relationship between edible meat content and serum protein levels described by Stewart et al (1967) holds true for ablated lobsters under these conditions.

The lobster culture project was also designed to answer questions regarding the effects of varying feed compositions on parameters such as growth and mortality, as well as the taste and texture characteristics of the post-molt, artificially fed product, and the overall economic viability of an industrial application of lobster culture using these techniques.

PREPARATION

Several tasks had to be performed before project lobsters could be acquired.

1. The plant's sea water supply system was to be put into running order and a back-up system was to be made available.

2. The plant was to be completely disinfected and to ensure that the disinfection had indeed been complete, water samples were to be checked subsequently for the presence of the gaffkemia producing bacteria.

3. The holding containers were to be modified to ensure that individual lobsters were satisfactorily isolated from one another.

4. Feed mixing and cooking equipment was to be put in running order.

5. Feed ingredients of suitable quality and quantity were to be acquired.

6. A record keeping system was to be designed to gather daily information on mortality, molting and post-molt weight gains for individually weighed lobsters. Records were to be kept on each individual lobster.

7. The staff was to be briefed on the general objectives of the project and trained in lobster handling, disinfection procedures, the use of the record keeping system, eyestalk ablation, feed manufacturing and storage, feeding, and other related duties.

Although a two month preparation period had been recommended after the last lobster culture project, delays in the contractual arrangements for this project allowed only two weeks for completion of the preliminary work listed above. In spite of this, however, the preparations were either complete or progressing satisfactorily at the end of the first week in May.

FACILITIES AND EQUIPMENT

A detailed description of the 'Swim Pound' lobster holding system is prohibited in order to protect the interests of Island Lobsters Ltd. It may be stated here, however, that its uniqueness lies in its ability to hold approximately 32,000 lobsters, each in its own individual container. The system's ability to arrest large-scale cannibalism is of considerable importance during the extended holding periods required for lobster growing.

Sea water was supplied to the building by means of pumping equipment that was located on a nearby government wharf. Water was drawn from a few feet below the surface immediately next to the wharf. Standby pumps and pipes were available on-site and a generator was available locally in case of power failure.

Feed manufacturing equipment consisted of a Hobart model 4346 mixer-grinder, and a Gaunt Steel Products two-compartment steam cooker with an operating pressure of 5 p.s.i. and a maximum capacity of 100 lbs. of feed.

Ablations were performed with Brown tonsil snares using gauge 5 or 6 wires, depending on the user's preference.

The facilities were verified to be disease free when several water samples from various locations in the building and its water discharge, and sediment samples taken from the holding pans were found to be devoid of the gaffkemia producing bacterium. Assistance with this diagnostic work was provided by the Fish Health Diagnostic and Control Unit of the Resource Branch of the Department of Fisheries and Environment.

LOBSTER ACQUISITION, SAMPLING AND ABLATION

The acquisition of project lobsters began on May 16. Freshly caught local lobsters were sorted on the wharf to isolate and select uninjured male lobsters weighing about one pound. In the pilot study, female lobsters had gained significantly less weight after molting (Castell et al, 1977). It has also been reported that crustacean ovarian development is encouraged by eyestalk ablation (Panouse, 1946; Brown and Jones, 1949), and egg production would have been an undesirable element added through the use of female lobsters.

The further constraint that no 'plugged' lobsters would be acceptable, since these would increase the risk of disease contamination, reduced the number of available lobsters from a projected 10,000 to 3,435. The local lobster fishing season closed at this point on May 31. The presence of gaffkemia in those 'plugged' lobsters was later confirmed when 3 of 10 tested lobsters held in a community tank were found to be infected. Yet not one gaffkemic lobster was found during the project's pre-ablation screening when 5% of all incoming lobsters were sampled.

Hemolymph taken during this sampling was also used to determine initial serum protein levels. The mean value was found to be 5.6% (±SD 2.1)[1] indicating good lobster condition (see Stewart et al, 1967). These sampled lobsters were also weighed individually so that individual post-molt weight gains could be determined.

Each group of 100 lobsters was held in its own separate section of individual containers and was weighed as a group when the lobsters were being put into the facilities. (The average individual lobster weight determined from the group weighings was 0.52 kg.) Furthermore, each section of 100 contained 5 of the lobsters that had been sampled and weighed as noted above. To determine whether the blood sampling affected growth, an additional 5 lobsters per section, for comparative purposes, were weighed individually, but not sampled. These 10 sampled and/or weighed lobsters were arranged in each section so that differences in growth, if any, attributable to varying positions within the sections could be documented. A 300 lobster intact control group was treated in the same manner.

A 1.3% mortality was incurred during the period between acquisition and ablation. Post-mortems revealed that many of these lobsters had been injured but that none had died of gaffkemia. The staff was instructed to take greater care when holding containers were pulled out during the daily inspection for mortalities, since this appeared to be the cause of the injuries. The injury rate decreased thereafter.

The ablations were performed within approximately 2 weeks of lobster acquisition, but not before disease-free status reports had been received. With 3 snares and 5 staff members it was possible to ablate a maximum of 100 lobsters per hour and the operations were completed on June 10. The post-operative mortalities of the week following ablation was 31 lobsters (1.0%) with 18 of these occurring on the first and second post-operative days.

FEED

It has been shown that in Long Island Sound lobsters feed mainly on crustacea, molluscs and other invertebrates, and small amounts of fish and marine palnts (Weiss, 1970). Research on lobster nutrition is in its early stages of development and commercial feeds may only be formulated on an empirical basis at the present time. The feed compositions used in this lobster culture project were modified versions of those used in the pilot study where formulations were based on knowledge of feeding under natural conditions and the limited information available on nutritional requirements. The diets were found to be adequate for growth and survival under the conditions of the pilot study. Modification of these feeds for use in both comercial scale studies were dependent on the availability of low cost ingredients and the binding characteristics of the resulting products. Careful attention was paid to feed quality and all factors ranging from the feed's formulation to its storage conditions were taken into consideration.

As this project progressed, the binding characteristics of feeds containing several different ingredients in various rations were tested. With the available binders, the major variable found to influence the feed's stability in water was its moisture content. This fluctuated when different batches of the same ingredients were used (crab and squid), and when ingredient ratios were varied. The compositions of three typical test feeds are given here to illustrate this point and to show how formulation affected feed costs. Feed preparation methods are outlined at the end of this section.

Ingredient	Diet No. C1 (%)	B1 (%)	G5 (%)
Crab	30	48	40
Lobster bodies	30	-	10
Squid	20	24	20
Powdered Irish moss[1]	5	5	9
White fish meal	5	2.5	7.5
Wheat middlings	10	20	10
Wheat gluten	-	-	2.5
Kelgin H.V.[2]	-	0.5	1

Feed number C1 was not found to be usable because it was too wet, yet it contained only 8% more wet ingredients than B1 (crab, lobster body and squid), which was an acceptably well-bound feed. Feed B1 did have a higher wheat middlings content, however, which probably reduced its final moisture percentage slightly. Furthermore, the lobster bodies, which are absent from B1 and reduced in G5, contained approximately 5% more water than the other wet ingredients. The exclusion of Kelgin from B1 did not appear to diminish the binding characteristics of this diet.

Feed type C1 was costed at 15¢/lb, feed B1 was 18¢/lb with Kelgin added and 17¢/lb with Kelgin omitted as opposed to a 25¢/lb cost for G5. Although these feeds were prepared at different stages of the project and their ingredient costs varied, the major cost differences were associated with the level of binders, which were the most expensive ingredients. In deciding which feeds were to be used in this project, costs were regarded as being of secondary importance. The rationale was that the lobsters should be fed as well as possible, and

[1] % = g. protein/100 ml. serum estimated by the Biruet analysis using a Technicon Autoanalyzer II.

[1] Carageenan - Marine Colloids Ltd., Dartmouth, N.S.
[2] Alginate - C. Tennant & Co. Ltd., Toronto, Ontario

an inexpensive but poorly bound feed would have been detrimental in this respect. Thus feed G5 was used for most of the trial period.

The feed preparation method, in brief, first involved grinding the frozen wet ingredients. These were then mixed with all the dry components except Kelgin and cooked for 45 minutes or until the mixture was hot throughout. The Kelgin was then added to the mixture which was remixed and extruded to produce pellets roughly 1/2" in diameter and 1" in length. Occasionally, the feed was laid out overnight on plastic sheets to reduce its moisture.

GROWTH PERIOD

Molting Incidence

The first ablated lobster to molt did so successfully 13 days after ablation. No more than 2 of these lobsters molted each day thereafter until the end of the first week in July, when the daily rate gradually increased. The total number of molts for each month of the growth period are summarized below. The control group's molts are given for comparison.

	June	July	Aug.	Sept.	Oct. 1-16	Total
Ablated Group Molts	10	186	573	878	345	1,992
Control Group Molts	1	5	11	11	9	37

The percentages of the ablated and control lobsters that molted are plotted against time in Figure 2 and show clearly that eyestalk ablation can be used to accelerate lobster molting under commercial conditions. The vertical arrows in Figure 2 indicate the times when the water supply to the lobsters was interrupted. These interruptions and the associated mortalities will be discussed later in the report. It should be noted here, however, that although only 63.5% of the initial 3,135 ablated lobsters had molted by October 14, 92% of all the lobsters had died because of several prolonged water supply interruptions.

It is also noteworthy that the high percentage of molts had occurred in spite of unexpectedly low water temperatures (Figure 3). The 1977 temperatures were lower than those of the 1976 trial, and the molting rate in the early part of the growth period did not climb as quickly as was desired. As a result, only a portion of the molted lobsters would have been satisfactorily hardened and meated for marketing purposes before the water temperature dropped again. However, as the project was underway, other problems were encountered that obviated these considerations. Two of these problems were that the individual holding pans were found to be too small, and the water supply was frequently interrupted. Disruption of the water supply eventually became the reason for the project's ultimate failure to answer all of the questions posed.

Molt Mortalities

Although the holding pans were large enough to hold up to a 2-1/2 lb lobster, movement during molting of the 1 lb lobsters was severely restricted. In some cases they were not able to pull their claws free from the cast shell. In others, lobsters suffered severe physical deformities as a result of being twisted in their pans after molting when the shell hardening process began.

It was found that among lobsters that had been weighed individually, post-molt mortalities were occurring more frequently in those with the highest initial weights (1-1/2 lb). To determine whether the small pans were the cause of a consistent 20-25% post-molt mortality rate, ablated lobsters that were just about to molt were placed in larger containers that did not restrict their movements. Once molting was complete the still soft lobsters were put back into their original pans and their position in the system was noted. Individual records kept on 69 of these cases showed that only one of these lobsters subsequently died for reasons that were not connected with the water flow disruptions. Furthermore, a staff member had noted that this particular lobster had experienced difficulties getting out of its shell. None of the lobsters allowed to molt in the large containers had the physical deformities previously noted.

The approximate dimensions of a pan that would not restrict a 1 lb lobster during its molt were calculated after molting of several lobsters in the large containers was observed. A pan whose length and width are a minimum of 12 inches each and whose water depth is at least 4 inches should allow a 1 lb lobster to molt freely.

Once a lobster had molted, its cast shell was removed from the pan and a piece of carapace removed from the feed containing cooked lobster bodies was substituted. Consumption of the carapace pieces was only slight. When whole cast shells were left in with each of 31 molted lobsters for 2 weeks, further reducing these lobsters' available space, there was no consumption of the cast shell.

Feed Consumption and Costs

The unablated lobsters often ignored their feed and would sometimes reject it by pushing it out of the pans. Even when they did feed they consumed considerably less than their ablated counterparts. It was found that that the control group could only be fed once a day and then with smaller amounts, otherwise the pans would become fouled with excess feed. The ablated lobsters were generally fed at least twice a day, 6 days a week. They often demonstrated a feeding behaviour similar to that observed by Conklin et al (1975) in a study involving the use of artificial diets for lobsters. A fresh piece of feed was readily consumed up to a point, when feeding stopped before it had all been consumed. A few minutes later when another fresh piece of the feed was given, feeding resumed on this but the other unconsumed piece was ignored and had to be removed to avoid fouling. In order to maximize feed intake with this type of feeding behaviour it was necessary to feed as often as possible giving small amounts each time. Whole mussels and clams were consumed without stopping, however, and 2 or 3 of these could often be given to an ablated lobster in rapid succession before the lobster was satiated.

The total weight of feed fed to the ablated

Figure 2: Molting incidences in ablated and control lobsters
(Water supply interruptions indicated by arrows)

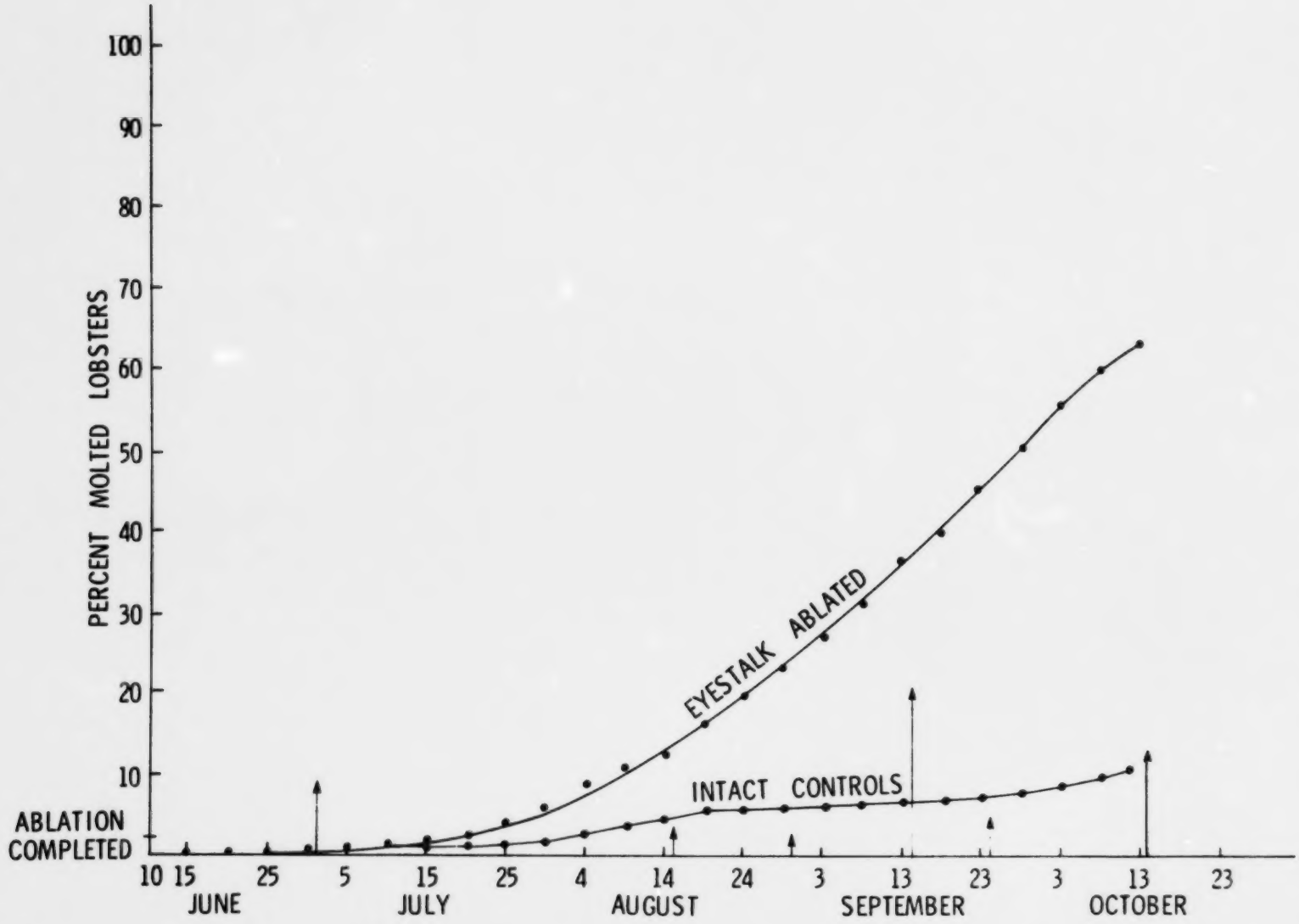
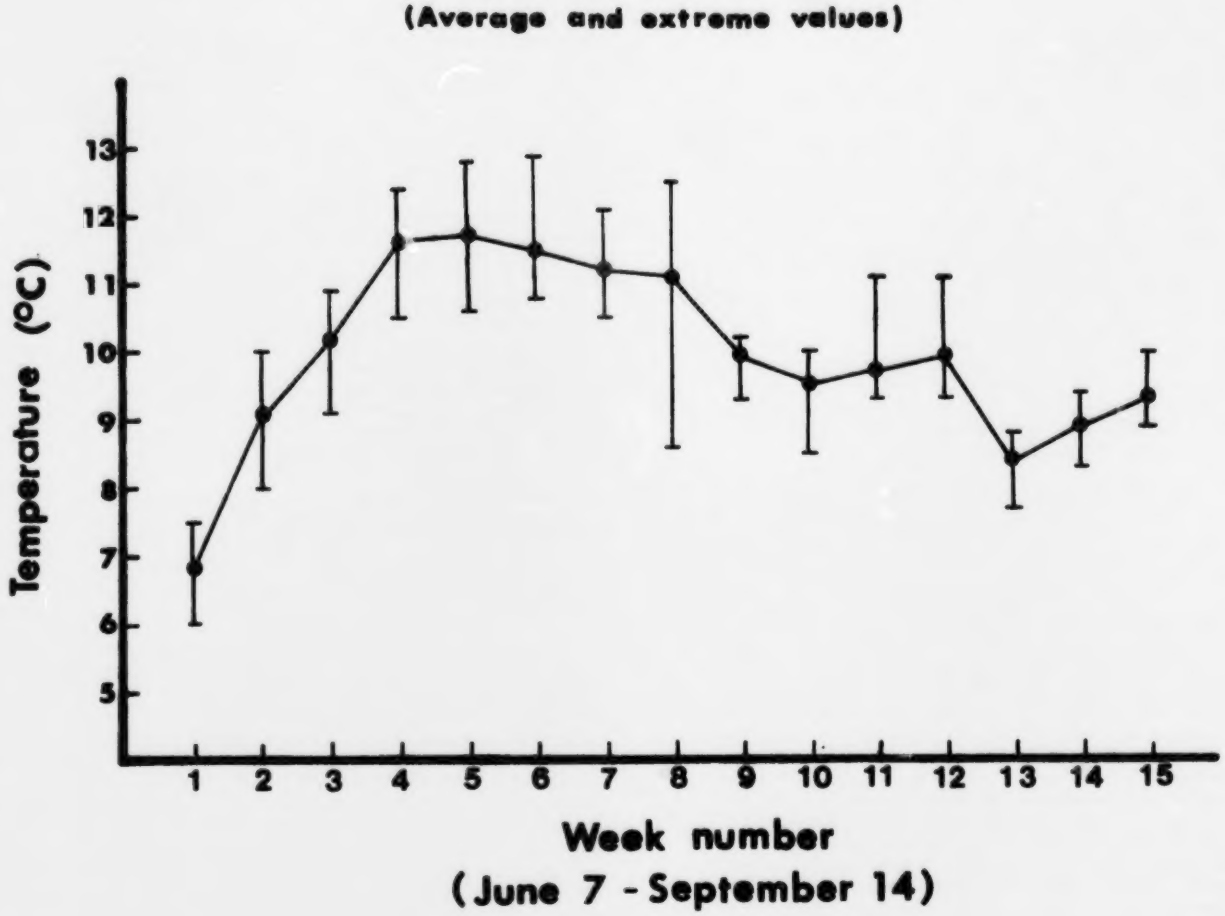


Figure 3: Water temperatures: weekly averages and extremes, Clark's Harbour, N. S.



lobsters in the course of the project was 3,263 lbs. This was approximately 1% of the lobster weight per day. At an average feed cost of 20¢/lb., feed costs were calculated at approximately 6¢ per ablated lobster, per month. On the other hand, the unablated lobster feed cost was below 2¢ per lobster, per month, at an average feeding rate of 0.3% of the lobster weight per day.

Water Supply Disruptions

The most persistent and ultimately the most important of the problems encountered in the course of the project was the matter of keeping the water supply going. The holding containers were designed so that the water drained from them if the supply was interrupted. This was a safety factor designed for short term interruptions to the water supply. Lobsters would quickly use up all the oxygen in the small volume of water in the container if it were not continually being replaced. Survival of lobsters is longer in air than in oxygen deficient water. There were, however, seven water supply interruptions whose durations were sufficiently long to cause high mortalities among the project lobsters. Soft shelled post-molt lobsters were the most affected by long exposure to air. The cumulative mortalities are plotted in Figure 4. The effect of the seven water supply interruptions is very clear. It was estimated that less than a total of 600 lobsters or 17.5% of the lobsters died for reasons other than water supply problems. There was a 1.3% mortality as a result of initial capture injuries, a 1.0% post-ablation mortality and a mortality of approximately 15% caused by space restrictions during molting.

On the evening of July 1 the sea water pump went off and stayed off overnight causing a 4% mortality of the project's lobsters. Roughly half of the recently molted lobsters died. On July 15, the water supply was again interrupted for several hours. There were large numbers of post-molt mortalities during the next few days. Two more interruptions occurred on August 15 and 30. Then a second serious interruption occurred on September 14 when the water was off overnight. The water intake was blocked by mud and seaweed that had been disturbed by wave action during a storm. Although there were still 2,011 of the original 3,435 lobsters left alive on September 19, damage to the project was greater than these numbers indicate. In order to obtain an adequate amount of meat of satisfactory texture from the ablated molts it was found that they required a minimum of three months feeding under the water temperature conditions of the project. Since the project was due to end in November, this meant that only lobsters that had molted by the end of August would have been suitable for test marketing, etc. On September 13, 543 of the 786 molts of June, July and August were still doing well. This represented over 1,000 lbs of lobsters that were earmarked for the shipping and taste evaluation tests. Unfortunately, only 91 of these molted lobsters survived the water shutoff, and no longer represented a commercially significant number of lobsters. Because the surviving lobsters had been severely stressed and could not be expected to give any further satisfactory information, it was recommended that the project be terminated. Island Lobsters, however, decided to continue the trial alone. The water supply was interrupted again in the early morning of September 28 and finally, between October 15 and 16, it was off for an estimated 15 hours because of a combination of a power failure and another storm. Only 10% of the lobsters survived, approximately two-thirds of these being from the unmolted control group.

RESULTS

Time to Molt

Serum protein levels have been shown to be a reliable indicator of the physiological condition of lobsters and are directly related to the molting cycle (Stewart et al, 1967; Ennis, 1973). Since individual records were kept for the molting dates of blood sampled lobsters throughout the project, a rough estimate of the period required for most of the remaining lobsters to molt was possible. Of 175 sampled lobsters, 84 molted in the course of the project and a linear regression analysis was performed on values for their days to molt and initial serum protein levels. It was calculated that over 90% of the lobsters (those with initial serum protein levels of 3% or more) could have been expected to molt by the end of November. The remaining unmolted lobsters would then have been subject to declining water temperatures and may have taken longer to molt. A low correlation coefficient of 0.7889, a product of the high degree of biological variability, indicated that a substantial error was involved in the estimate. When the number of molts due in November were estimated on the basis of the previous molting rates, however, it was indicated again that most of the lobsters would have molted by the end of that month.

Since space restriction has been shown to limit molting incidence (Stewart and Squires, 1968) this overall 5 month pre-molt period may not have been as long under less restrictive conditions. Other adverse conditions may also have delayed molting.

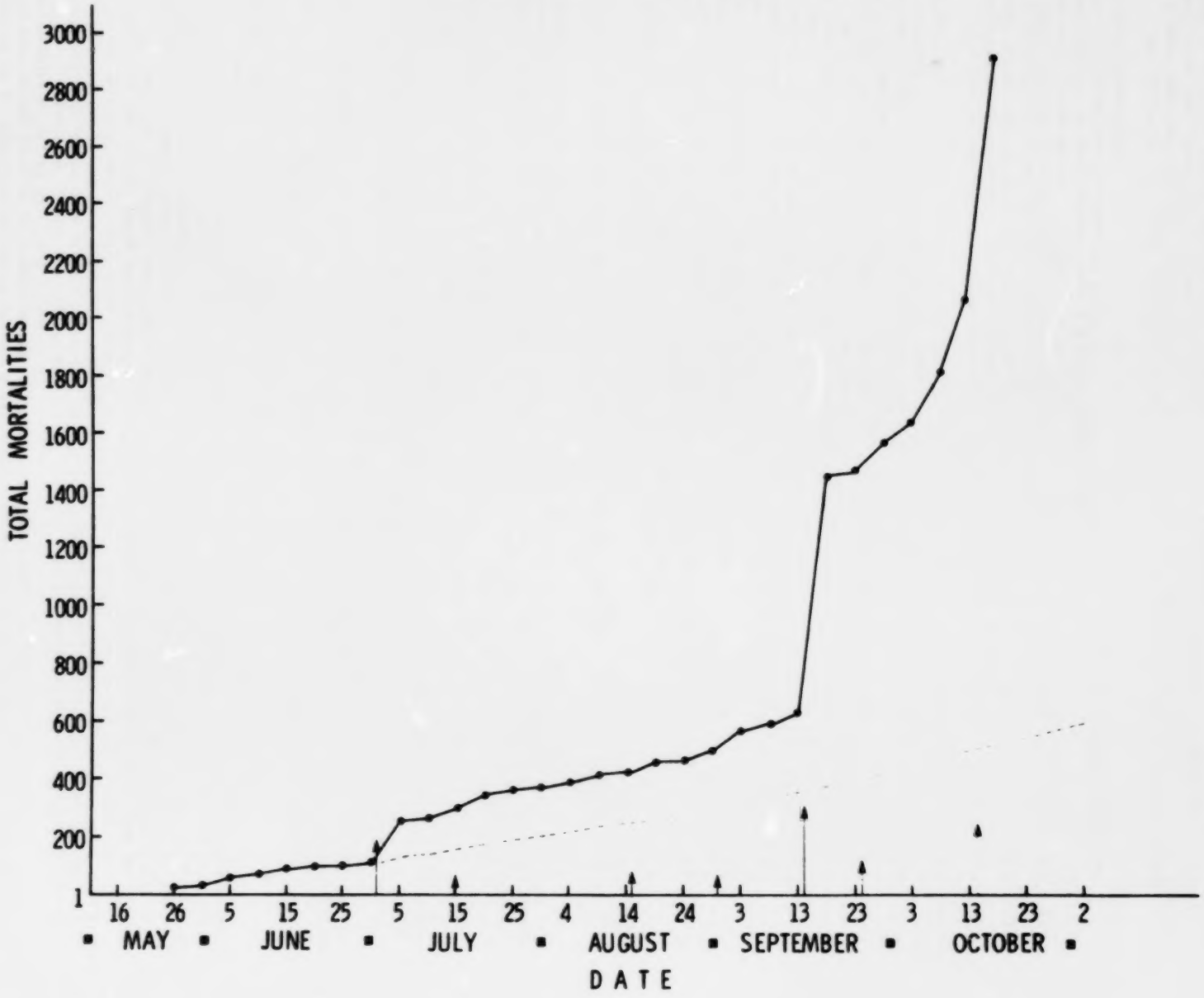
The pre-molt period is of considerable importance not only as far as the growth period planning is concerned, but also in relation to the overall economic viability of commercial lobster culture using these techniques. The period may be decreased by acquiring lobsters for growth that are known to be approaching molt (See Stewart and Li, 1969) or by locating a culture site where the summer increase in water temperatures is greater than experienced in the summer of this project. In the long term it may be economically feasible to use solar energy or thermal effluent in conjunction with water recirculation (if gaffkemia is absent) to grow lobsters at artificially elevated water temperatures. Higher water temperatures may also decrease the fill-out period but on the other hand may contribute to disease problems.

Finally, as an alternative to waiting for every lobster in a particular group to molt, a cut-off date may be assigned and any animals that have not molted by then could be sold as ablated but otherwise normal hard shelled lobsters. At this point a distinctly separate fill-out stage would begin, specialized diets formulated to aid in shell hardening could be employed for meating out the molted ablated lobsters.

Weight Gain

When a lobster molted for which an individual

Figure 4: Cumulative mortalities
(Water supply interruptions indicated by arrows)



weight had been recorded, its percent weight gain was calculated on the basis of its weight on the seventh post-molt day. The mean post-molt weight gain of 78 ablated lobsters was 71.5% (±SD 9.2). The mean weight gains of 42 blood sampled and 36 non-sampled molts, 69.8% (±SD 8.3) and 73.4% (±SD 9.9) respectively, were not significantly different. No weight gain variations related to position in the system were detected. Although only one post-molt weight gain value could be obtained from the control group for comparison (25.3%) (only 10% of lobsters were individually weighed), the greater size attained by ablated lobsters was apparent throughout the project. The most striking difference between ablated and non-ablated lobsters was seen in their post-molt claw expansions. The greater weight gains by ablated lobsters were caused by greater water uptakes following the molt, which were accompanied by increased dilution of body fluids. This was reflected in post-molt serum protein levels which were consistently below 1% for ablated lobsters and approximately 2% for control lobsters.

Shleser (1974) suggested that space limitations reduce lobster growth even before the animal is physically restricted. This agreed with the earlier finding of McLeese (1972) that increased lobster storage densities in communal tanks were accompanied by reduced post-molt weight gains. The effects of container size on weight gain, molting incidence, survival and capital costs will have to be well documented before optimum results are achieved in a commercial application of the technology under discussion.

Edible Meat, Shell Hardening and Fill-Out Period

After the overnight water flow disruption of September 14, 29 ablated and 10 normal lobsters at various post-molt stages were retained for edible meat content and serum protein level determinations. After hemolpmph samples were taken, these lobsters were cooked in boiling sea water for 15 minutes and the claw and tail meat removed and weighed. The mean percent edible meat for the ablated lobsters and individual values for the control group were plotted against weeks post-molt in Figure 5. The mean percent meat content of the ablated lobsters was less than that of the controls as the former gained considerably more weight at molt than the latter. The decrease in meat weight from the molting date to 8 weeks post-molt in both groups was not the result of true meat loss but a decrease in the water content of the flesh (Figure 6).

The meat of the lobsters 2 weeks post-molt contained about 91% water. This was reduced to about 86% by the 8th post-molt week. Although the percent edible meat did not decrease after 8 weeks post-molt the percentage of dry components (protein, carbohydrate, lipid etc.) in the meat continued to increase between weeks 8 and 12. This indicated true increases in flesh or protein disposition.

The texture of the cooked meat from lobsters 2-6 weeks post-molt was soft and jelly-like. It would have been unacceptable to most consumers. After 8 weeks the cooked meat was firm, compared favorably in taste with wild lobsters and would have been acceptable to most consumers. Although the meat yield was still somewhat low at 12 weeks post-molt, the general indication was that the ablated lobsters would have been excellent marketable lobsters within the next two months. From Figure 6 it appears as though at least 4 or more post-molt months would have been required for the animals to become fully meated.

Shell hardening was satisfactory at the 3 months post-molt stage. The 3 month post-molt serum protein levels remained low at 1% for ablated and slightly over 2% for the molted control lobsters. Dietary factors might have been responsible for the slower recovery from the molt in the present project compared with the smaller culture experiment at St. Andrews, New Brunswick, however, low water temperatures, adverse conditions imposed by the small holding containers and the water flow interruptions were probably also deleterious factors.

It is known throughout the industry that recently molted lobsters are not to withstand as much shipping and handling stress as hard shelled ones; by the time they reach the consumer, higher numbers of soft shelled lobsters have died. Furthermore, many regular consumers are aware that relatively soft shelled lobsters are poorly meated and will avoid their purchase if possible.

Feed Analysis

The results of feed and feed ingredient analyses performed at the end of the project are tabulated below. Ash, nitrogen and lipid values are given as percentages of the dry material.

Feed or Ingredient	Moisture (%)	Total Nitrogen (%)	Lipid (%)	Ash (%)
Crab	68.3	6.2	5.8	28.3
Lobster body	75.8	7.9	13.2	27.2
Squid	71.1	8.0	12.4	18.9
P.I.M.	19.8	2.2	0.5	?
K.H.V.	19.7	0.3	0.2	?
Cod heads	59.3	5.9	3.3	25.5
Wheat middlings	10.9	2.6	4.9	3.1
White fish meal	6.4	10.3	6.6	33.2
G5	56.4	6.2	4.5	28.2

COMMERCIAL ECONOMIC VIABILITY

The economic viability analysis below, based on the application of eyestalk ablation techniques with 30,000 lobsters, included the following assumptions:

1. The operation's duration would involve 9 months of lobster holding (Exhibits I and III) which may be reduced to 6 months if

Figure 5: Mean (±SD) percent edible meat in ablated lobsters and individual control group values

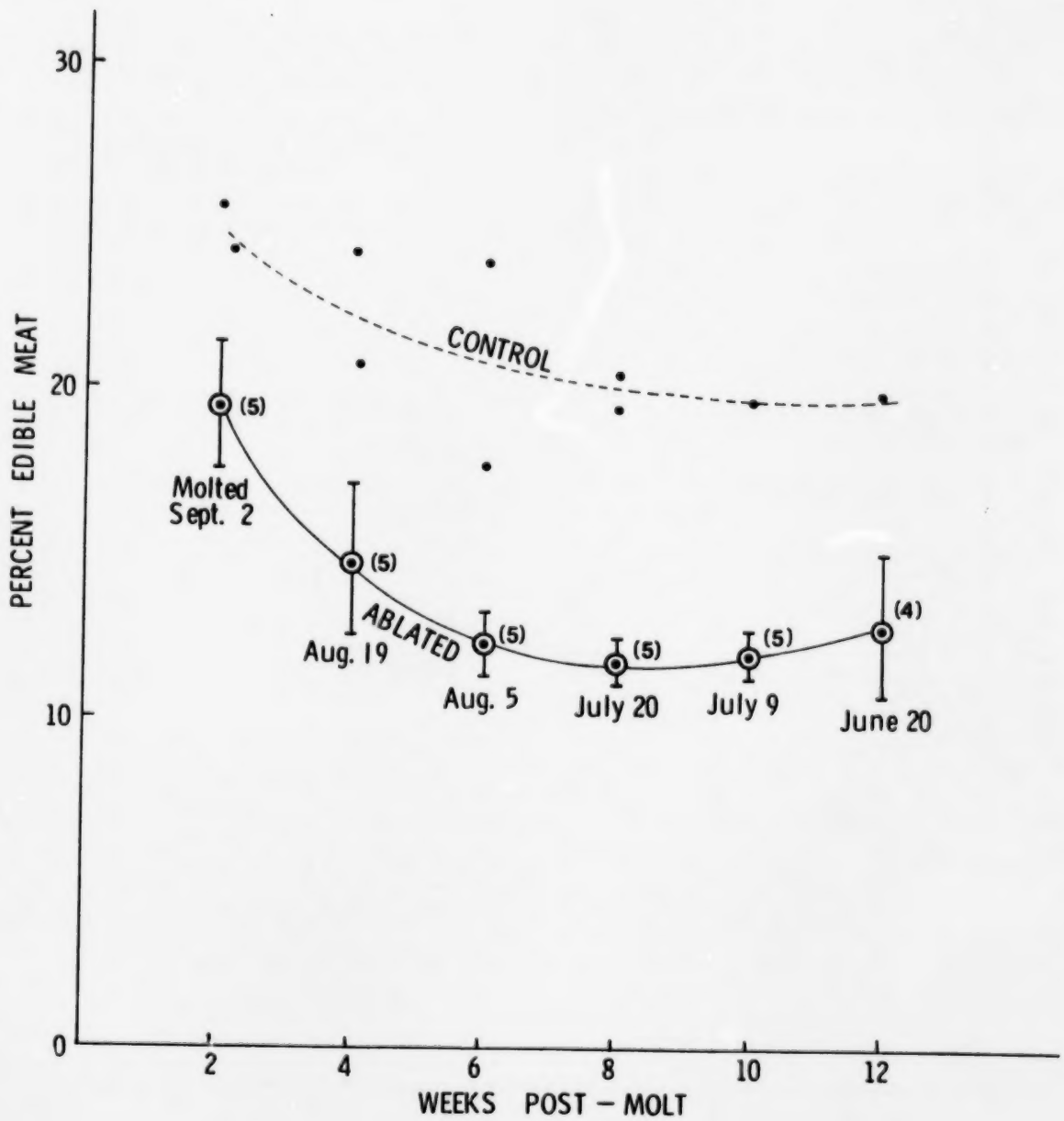
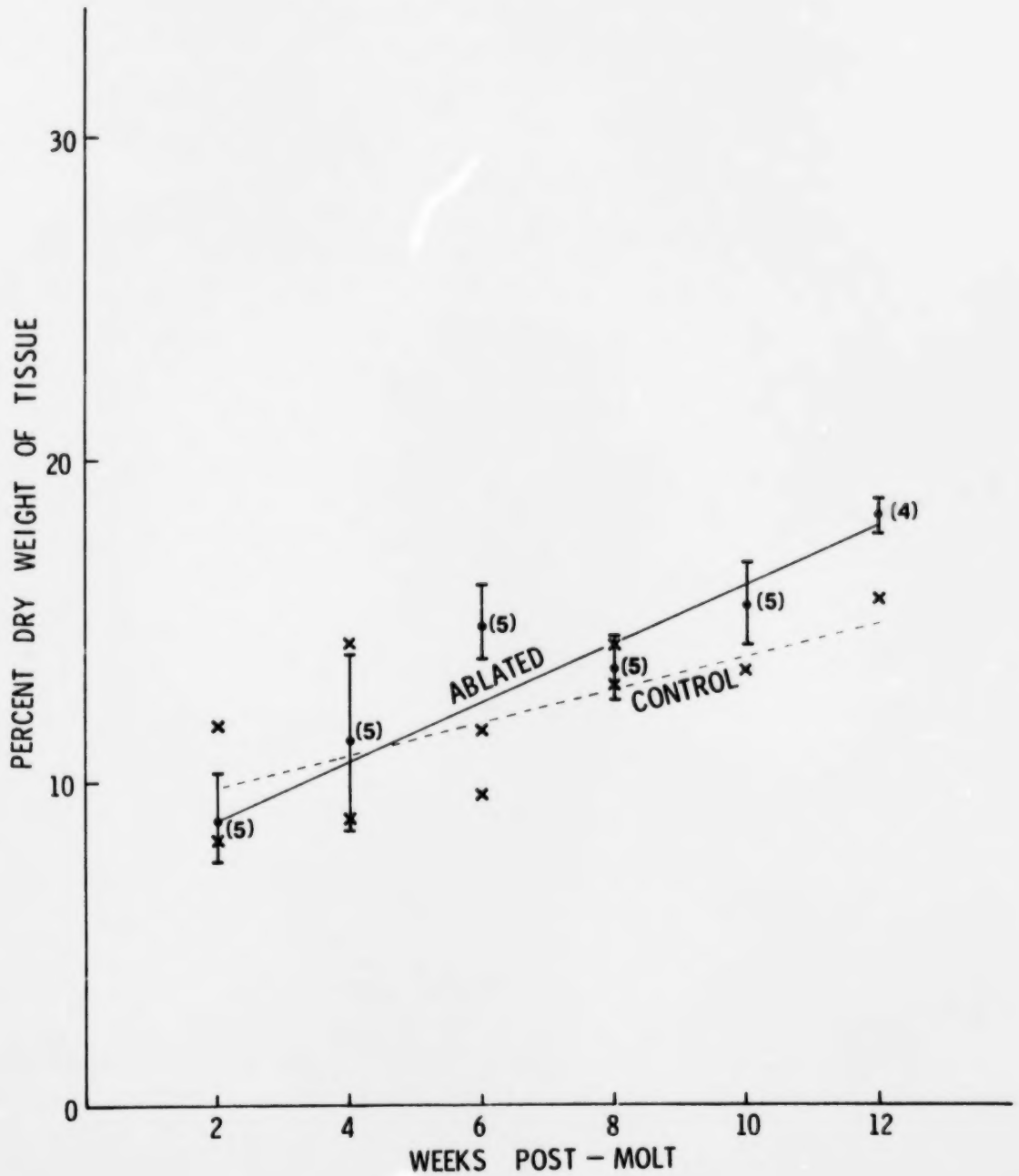


Figure 6: Percent dry weight of tissue in post-molt ablated and control lobsters



the required technological refinements are made (Exhibits II and IV). This would allow 2 lobsters growing cycles a year.

2. The feed costs are based on an average feeding of 1% of the initial lobster weight per day in feed at 20¢/lb over 9 months.

3. The feed costs would be equivalent in a 6 and 9 month cycle because of increased feed consumptions during the shorter period (due to elevated water temperatures, etc.).

4. The 30,000 lobster per cycle unit would require 6 workers for feeding and maintenance, a clerk and a manager.

5. A 10% mortality may be incurred with 25% of the mortality weight recovered as saleable meat (at $6.00/lb).

6. The finished product sale price is $3.25/lb.

7. The operator borrows the money required to finance a capital cost of $225,000 for facilities and equipment.

8. Other expenses are roughly equivalent to those of the feasibility study (utilities, etc.).

9. The potential revenue from the sale of cast shells to souvenir manufacturers is ignored.

General scenarios have been prepared which illustrate the effect of varying lobster purchase price ($1.65, $2.00 and $2.50/lb) on cash flow when either 1 or 1-1/2 lb lobsters gain an average of 70% in weight. The cash flow statements and the comments amplifying them were prepared by Mr. D. Lemon of the Technology Branch, Fisheries and Marine Service, Maritimes Region, Halifax, Nova Scotia

The following exhibits represent pro forma cash flows. Cash flow statements simply describe the cash generated by an operation and the cash requirements of that operation. These statements, although somewhat similar to income statements, are not be confused with them. For example, depreciation, which would appear on an income statement, is not included in a cash flow analysis because it is not a real expense. Similarly, only interest on long term debt would appear as an expense on an income statement, however, because the principal must be repaid, both principal and interest are accounted for in a cash flow analysis. A cash flow analysis is especially useful when attempting to predict the economic viability of new, relatively small businesses. A major cause of failure in this sort of enterprise is a shortage of working capital, that is, the firm becomes 'cash poor'.

One important point should be made with reference to the accompanying exhibits. We have assumed that the firm will borrow in excess of $200,000 to finance its capital requirements, thus the firm will be tied to a heavy repayment schedule. If another form of financing were available, it might well be that the marginal projects would become viable.

CONCLUSIONS

Although the project failed to meet its final objective of marketing cultured lobsters, it was a qualified success. The eyestalk ablation technique produced the same growth enhancing effects in a commercial context as in the laboratory and could be performed satisfactorily by lay workers. Ablated lobsters reached their molts more quickly and those with initial weights of 1-1/2 lbs often attained 2-1/2 lbs after molting. Weights gains were consistently around this 70% mark.

It was shown that through appropriate precautionary measures, disease may be avoided altogether. It was found that further work is required in the following areas:

1. Feed Development - improved binding, reduced costs and nutritional evaluation.

2. Holding Containers - optimum size for good survival and lowest capital cost.

3. Water Temperature - relationship to pre- and post-molt periods in terms of molting incidence, fill-out and hardening time.

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EXHIBIT I

PRO FORMA CASH FLOW

(1 lb. lobster as raw material)

For 1 operating year, assuming lobsters sold after 9 months' holding

	Raw Material @ $1.65/lb		Raw Material @ $2.00/lb		Raw Material @ $2.50/lb	
Sources of Funds:						
Sale of lobsters	$149,175		$149,175		$149,175	
Sale of meat recovered	4,500		4,500		4,500	
Total		$153,675		$153,675		$153,675
Uses of Funds:						
Raw material	49,500		60,000		75,000	
Feed	16,200		16,200		16,200	
Labour [1]	67,597		67,597		67,597	
Utilities	7,650		7,650		7,650	
Repairs and maintenance	2,000		2,000		2,000	
Debt repayment [2]	25,000		25,000		25,000	
Total		$167,947		$178,447		$193,447
Net Cash Flow:		($14,272)		($24,772)		($39,772)

[1] Six workers and one clerk costing an average of $4.50/hr., 7 hours a day, 6 days a week for 39 weeks, and a salaried manager @ $16,000 p.a.

[2] Assume $225,000 mortgage amortized over 25 years @ approximately 10%

EXHIBIT II

PRO FORMA CASH FLOW

(1 lb. lobster as raw material)

For 1 operating year, assuming two six-month seasons

	Raw Material @ $1.65/lb		Raw Material @ $2.00/lb.		Raw Material @ $2.50/lb.	
Sources of Funds:						
Sale of lobsters	$298,350		$298,350		$298,350	
Sale of meat recovered	9,000		9,000		9,000	
Total		$307,350		$307,350		$307,350
Uses of Funds:						
Raw material	99,000		120,000		150,000	
Feed	32,400		32,400		32,400	
Labour	84,796		84,796		84,796	
Utilities	10,200		10,200		10,200	
Repairs & maintenance	2,000		2,000		2,000	
Debt repayment	25,000		25,000		25,000	
Total		$253,396		$274,396		$304,396
Net Cash Flow:		$ 53,954		$ 32,954		$ 2,924

EXHIBIT III

PRO FORMA CASH FLOW

(1 1/2 lb. lobster as raw material)

For 1 operating year, assuming lobsters sold after 9 months holding

	Raw Material @ $1.65/lb		Raw Material @ $2.00/lb		Raw Material @ $2.50/lb.	
Sources of Funds:						
Sale of lobsters	$219,375		$219,375		$219,375	
Sale of meat recovered	6,750		6,750		6,750	
Total		$226,125		$226,125		$226,125
Uses of Funds:						
Raw material	74,250		90,000		112,500	
Feed	24,300		24,300		24,300	
Labour	67,597		67,597		67,597	
Utilities	7,650		7,650		7,650	
Repairs & maintenance	2,000		2,000		2,000	
Debt repayment	25,000		25,000		25,000	
Total		$200,797		$216,547		$239,047
Net Cash Flow:		$ 25,328		$ 9,578		($12,922)

EXHIBIT IV

PRO FORMA CASH FLOW

(1 1/2 lb. lobster as raw material)

For 1 operating year, assuming two six-month seasons

	Raw Material @ $1.65/lb.		Raw Material @ $2.00/lb.		Raw Material @ $2.50/lb.	
Sources of Funds:						
Sale of lobsters	$438,750		$438,750		$438,750	
Sale of meat recovered	13,500		13,500		13,500	
Total		$452,250		$452,250		$452,250
Uses of Funds:						
Raw material	148,500		180,000		225,000	
Feed	48,600		48,600		48,600	
Labour	84,796		84,796		84,796	
Utilities	10,200		10,200		10.200	
Repairs & maintenance	2,000		2,000		2,000	
Debt repayment	25,000		25,000		25,000	
Total		$319,096		$350,596		$395,596
Net Cash Flow:		$133,154		$101,654		$ 56,654

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